Scarp Retreat and Recent Exposure

- Why is it important?
- What does it look like on the ground?
- How do we evaluate this criterion from orbit?

Melissa Rice, with input from the Mastcam-Z Team

2nd Mars 2020 Landing Site Workshop
4 August 2015

Recent exhumation included in Summons et al. (2011) study for MSL landing site selection process

Martian context → early Mars environment	*Support biotic OM formation*	*Support for abiotic OM formation*	*Support OM concentration*	*Support preservation*	*Potential for recent exhumation**
Eolian sediments (sand)	low	low	low	low	low ??
Altered eolinites (dust)	very low	low	low	low	low ??
Fluvial channel	low	low	low	low	high
Fluvial floodplain	low-mod	low	mod	mod	possible ??
Alluvial fan	low	low	low	low	low ??
Deltaic	high	low	high	high	low ??
Lacustrine (perennial)	high	low	high	high	high
Lacustrine (evaporitic)(Cl)	low	low	high	high-very high	high
Lacustrine (evaporitic)(SO_4)	mod	low	high	high-very high	high
Regional groundwater pore system	low	low	low	low	high ??
Glacial deposits	low	low	low	low	high
Permafrost	low	low	low	mod	mod
Soil (surface fines chemically altered by atmosphere)	low	low	low	low	low
Regolith/Fractured bedrock (not soil)	low	low	low	low	low

Summons et al. (2011), Table 3

Landing Site Factor	Mars 2020 Mission and Decadal Priority Science Factors																						
	Environmental Setting for Biosignature Preservation and Taphonomy of Organics								Type 1A & 1B Samples: Aqueous Geochemical Environments indicated by Mineral Assemblages									Type 2 Samples: Igneous		Context: Martian History Sampled, Timing Constraints				
	Deltaic or Lacustrine (perennial)	Lacustrine (evaporitic)	Hydrothermal (<100°C) surface	Hydrothermal (<100°C) subsurface	Pedogenic	Fluvial/Alluvial	No diagenetic overprinting	Recent exposure	Crustal phyllosilicates	Sedimentary clays	Al clays in stratigraphy	Carbonate units	Chloride sediments	Sulfate sediments	Acid sulfate units	Silica deposits	Ferric Ox./Ferrous clays	Igneous unit (e.g, lava flow, pyroclastic, intrusive)	2nd Igneous unit	Pre- or Early-Noachian Megabreccia	Oldest stratigraphic constraint	Youngest stratigraphic constraint	Stratigrapy of units well-defined	Dateable surface, volcanic (unmodified crater SFD)
Recentis Exposialis	○	~		~		●	~	●	~	○								~		~	LN	EA	●	
Exposus Ambigutitus	●	~				○		~		~	~				○		~	~			EH		~	
Malus Exposialis	●					●				~	~	○		~			~	~			EN	MH		

"Recent Exposure" included on landing site rubric

Key	
●	Yes (in-ellipse)
○	Yes (out of ellipse)
	No
~	Partial Support or Debated
?	Indeterminate
	TBD

"Enviro & Taphonomy" tab in the rubric

Environmental Setting for Biosignature Preservation and Taphonomy of Organics				
Environment	**Summons et al., 2011**			Additional Recent References
	Formation	**Concentration**	**Preservation**	
Deltaic/Lacustrine (perennial)	high	high	high	
Lacustrine (evaporitic)	low-mod	high	high	
Hydrothermal (<100°C) surface	high	mod-high	mod	
Hydrothermal (<100°C) subsurface	mod	low-mod	mod	
Pedogenic*	mod	low-mod	low-high	Retallack et al (2000) GSA Spec Pub; Gay & Grandstaff (1980) Prec Res
Fluvial/Alluvial	low-mod	low-mod	low-mod	
No diagenetic overprinting (e.g., no evidence for later oxidation, dissolution/recrystallization, high temperatures (p173))	-	-	high	
Recent exposure* to limit radiation damage (e.g. active scarp retreat; observed recent crater; low density of 10-20m craters)	-	-	high	Farley et al. (2014) DOI:10.1126/science.1247166

Multiple values indicate possible range depending on local conditions.

Adapted from: **Summons et al. (2011)** DOI:10.1089/ast.2010.0506
*Additional environments/constraints not discussed in Summons et al. (2011)

Possible means of identifying active erosion and recent exposure in orbital datasets:

1. Crater degradation and paucity of small impacts
   → *Indicative of a deflating surface (see Edwin Kite's presentation)*

2. Boulder-shedding off cliffs/scarps
3. Consistent, regional orientation of scarps
   → *Indicative of scarp retreat, active landscape evolution*

1. Dark sand deposits / dune fields
   → *Indicative of active abrasion by sand*

2. Yardangs / wind-sculpted outcrop
   → *Indicative of aeolian abrasion*

1. Locally "bluer" hues in HiRISE color
2. Clear CRISM spectral signatures
   → *Indicative of recent dust removal (but perhaps not long-term erosion)*

Farley et al., Science (2014)

Recent exposure at Gale Crater as seen by MSL

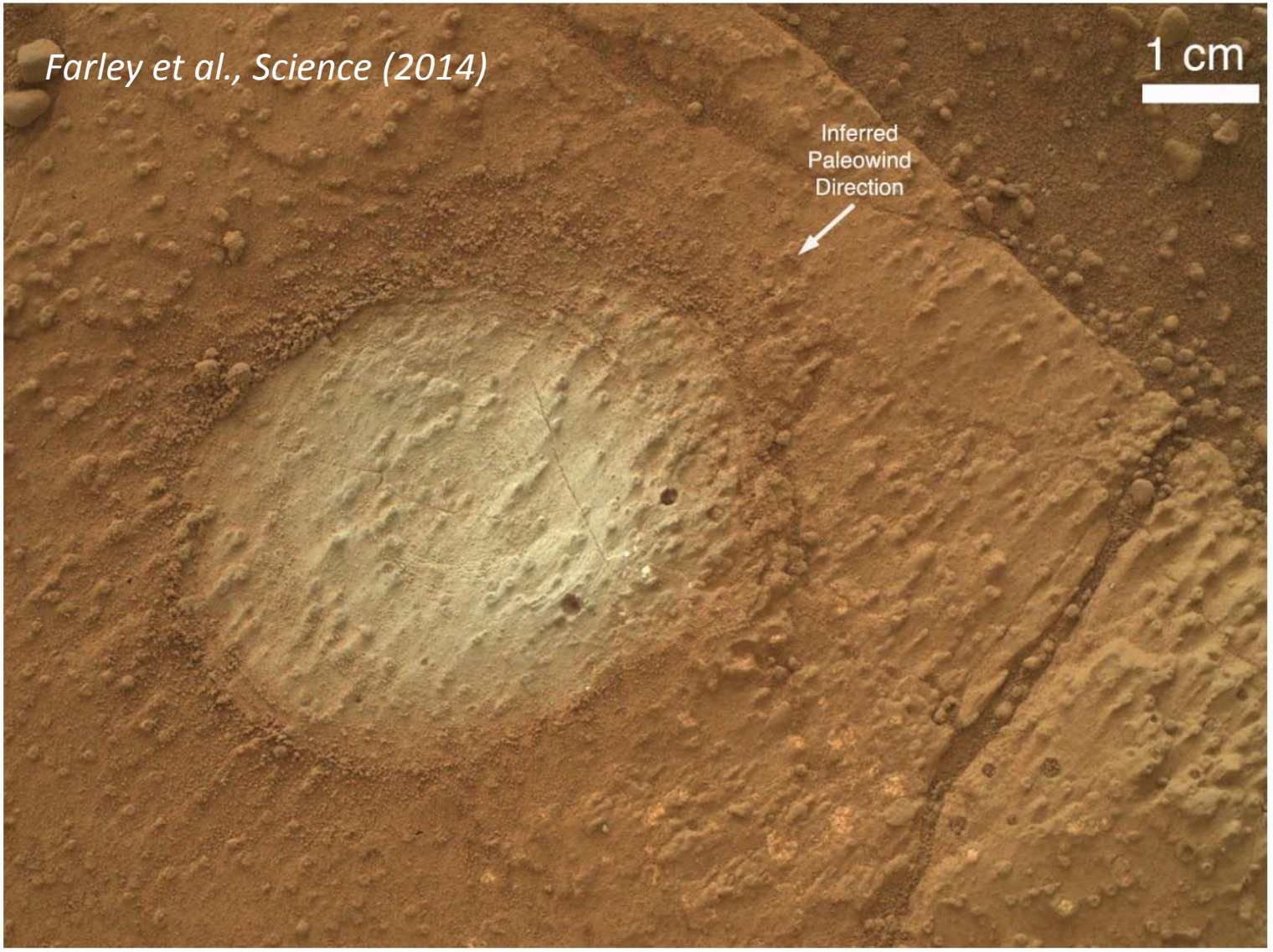
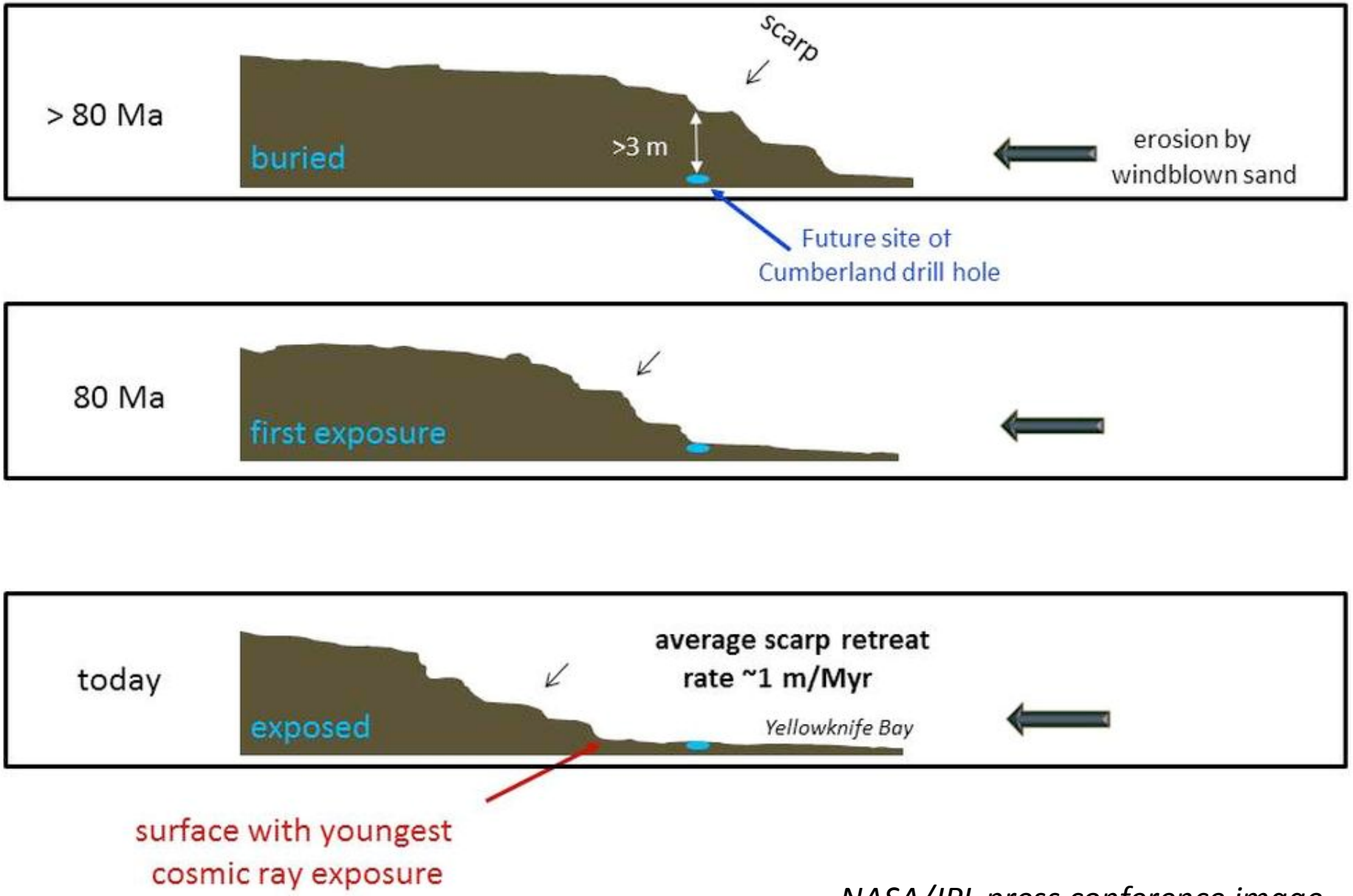


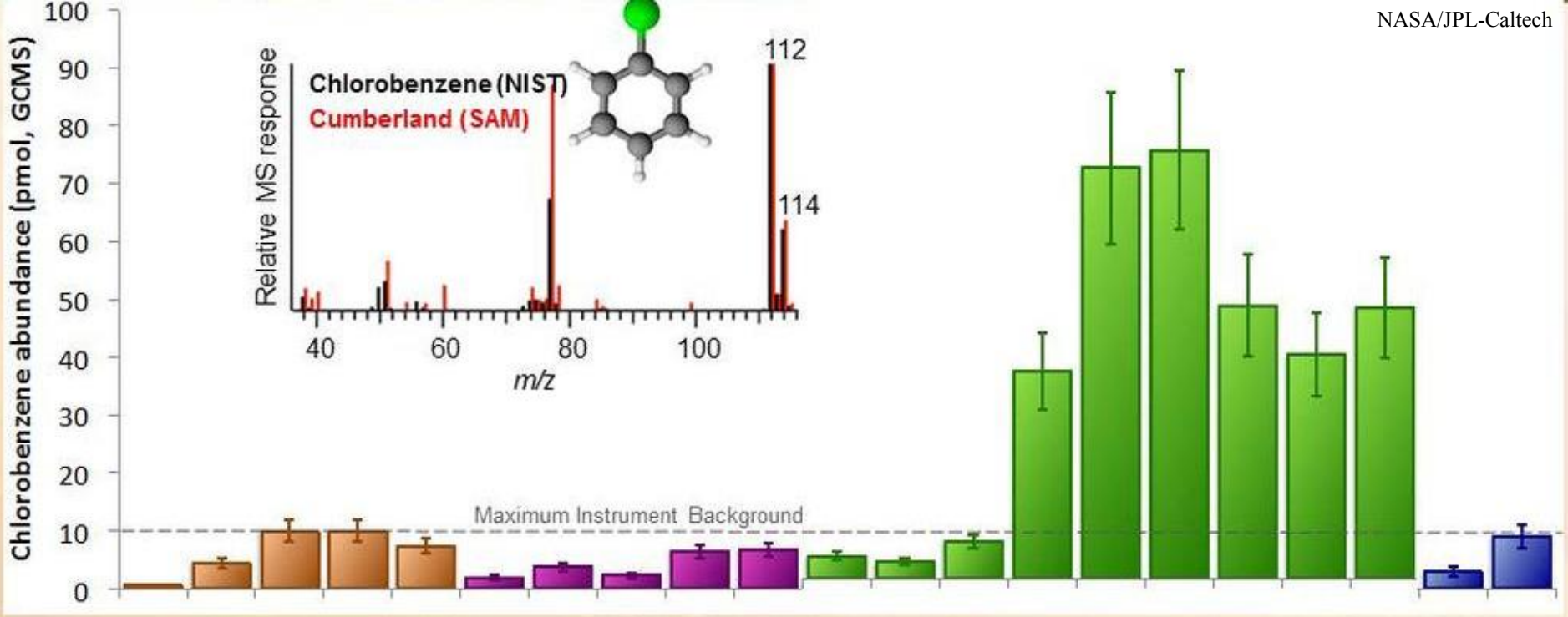
Fig. 2. Mars Hand Lens Imager (MAHLI) image of brushed, gray bedrock outcrop of Sheepbed mudstone near the Cumberland drill hole. Protrusion of nodules (*9*) results from eolian scouring of rock surface, creating wind tails. Preference for steep faces of wind tails on northeast side suggests a long-term averaged paleowind direction from northeast to southwest. This is a portion of MAHLI image 0291MH0001970010103390C00, acquired on sol 291. Illumination from the upper left.

Scarp Retreat Model and Exposure History of Yellowknife Bay



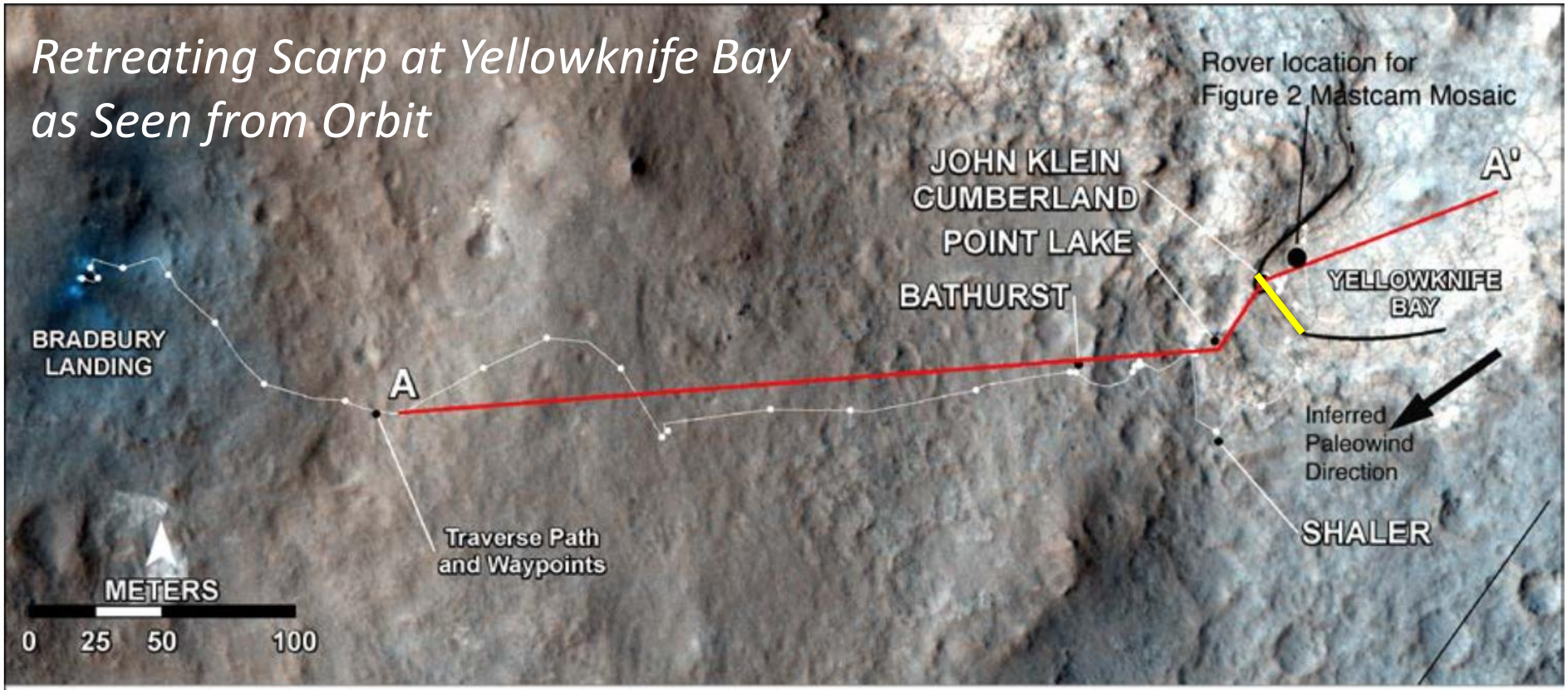
NASA/JPL press conference image

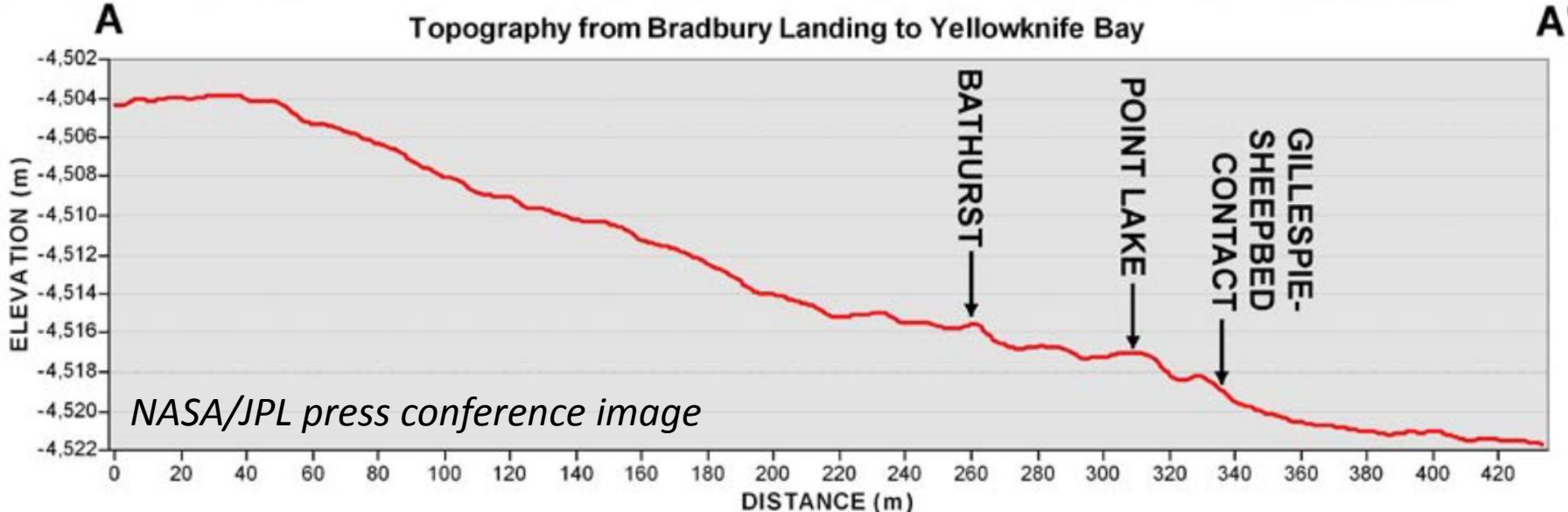
NASA/JPL-Caltech



The organic chemical chlorobenzene was detected in the Cumberland drilled sample. The chlorine likely is derived from perchlorate in the sedimentary rock.

CURIOSITY


Retreating Scarp at Yellowknife Bay as Seen from Orbit
Rover location for Figure 2 Mastcam Mosaic
JOHN KLEIN
CUMBERLAND
POINT LAKE
BATHURST
A'
YELLOWKNIFE BAY
BRADBURY LANDING
A
Inferred Paleowind Direction
SHALER
Traverse Path and Waypoints
METERS
0 25 50 100


A
Topography from Bradbury Landing to Yellowknife Bay
A'
ELEVATION (m)
-4,502
-4,504
-4,506
-4,508
-4,510
-4,512
-4,514
-4,516
-4,518
-4,520
-4,522
BATHURST
POINT LAKE
GILLESPIE-SHEEPBED CONTACT
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420
DISTANCE (m)
NASA/JPL press conference image

HiRISE Color Mosaic of the Kimberly Region
NASA/JPL-Caltech/HiRISE/C. Edwards

Scarps in the same "smooth" unit above "striated" unit appear to be eroding in the same WSW direction as the scarp at Yellowknife Bay

→ *Potentially a regional trend of exhumation*

200 m


N
Meters
0 10 20 40 60 80 100

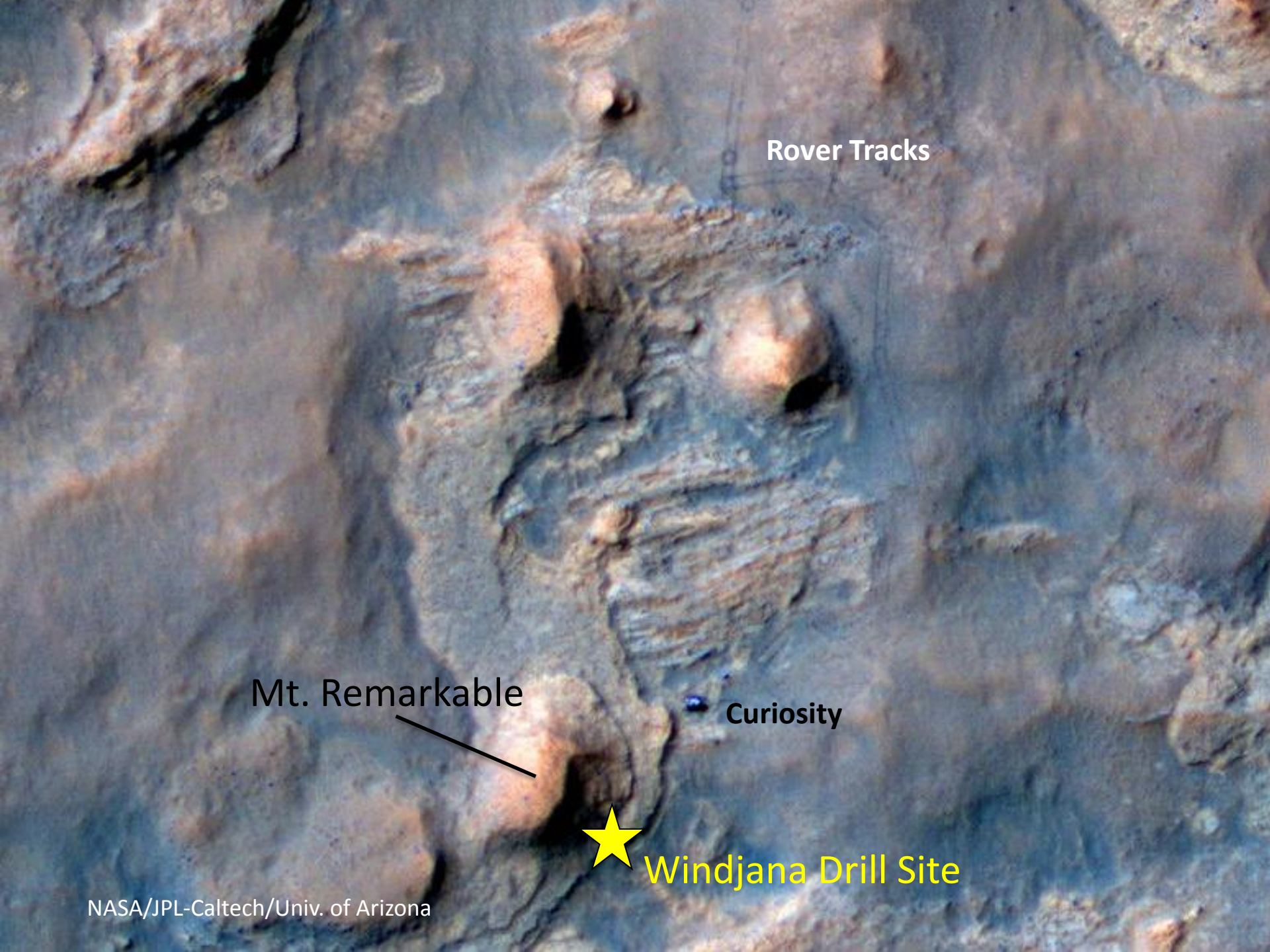
View of the Kimberley looking south

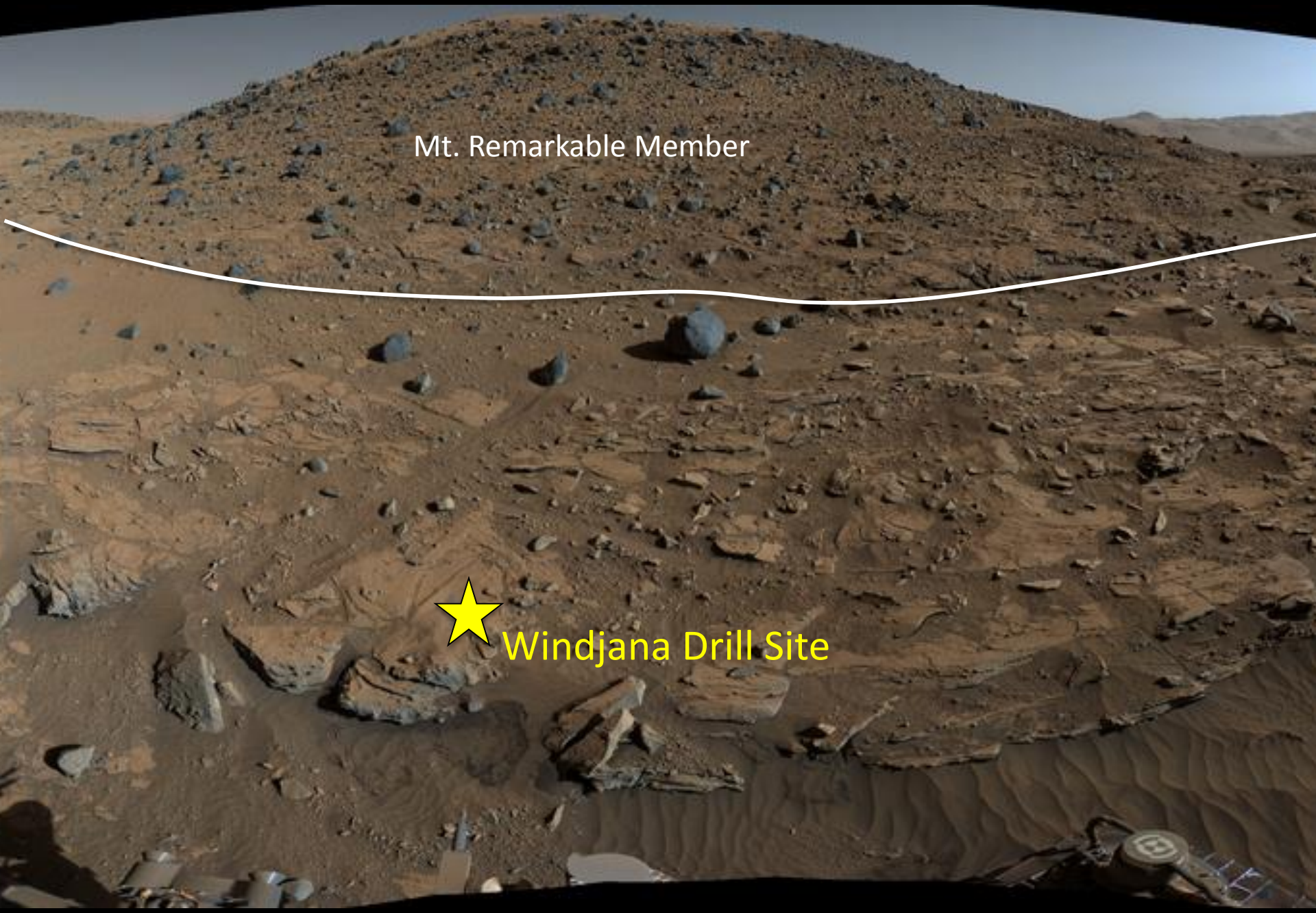
NASA/JPL-Caltech/MSSS

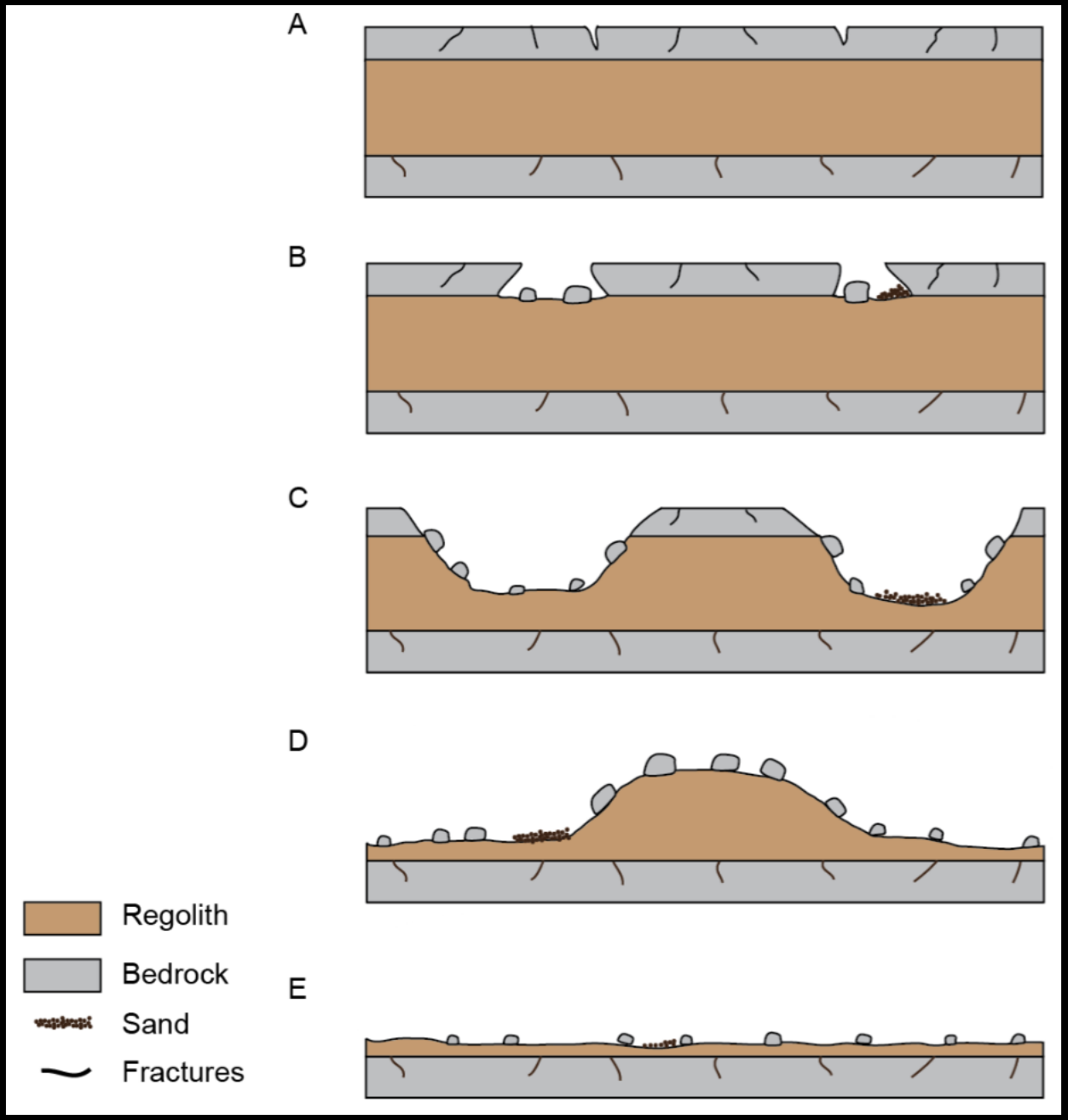
Mastcam-Left mosaic, sol 580


NASA/JPL-Caltech/MSSS


Square Top
Sol 583, 6.9 cm working distance, focus merge
02583MH0001730010202004C00
Yingst et al., GSA, 2014
5 mm


Rover Tracks
Mt. Remarkable
Curiosity
Windjana Drill Site
NASA/JPL-Caltech/Univ. of Arizona


Mt. Remarkable Member
Windjana Drill Site



Model for Landscape Evolution

Day & Kocureck, in review

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Exposus Ambigutitus	●	~				○		~		~	~				○		~	~			EH		~	
Malus Exposialis	●					●				~	~	○		~			~	~			EN	MH		

So how do we evaluate this column in the rubric?

Key	
●	Yes (in-ellipse)
○	Yes (out of ellipse)
	No
~	Partial Support or Debated
?	Indeterminate
	TBD

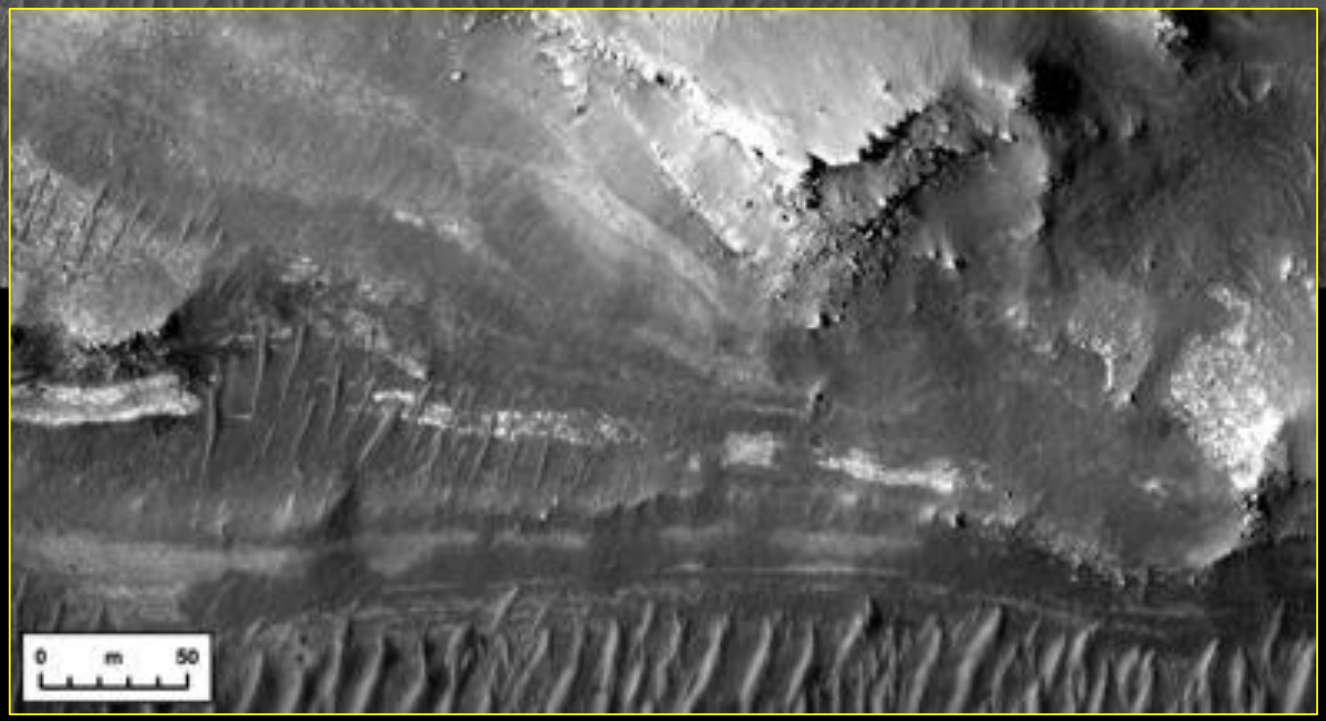
Examples of good evidence for recent exposure

(dots in the rubric)

Cliffs Shedding Boulders

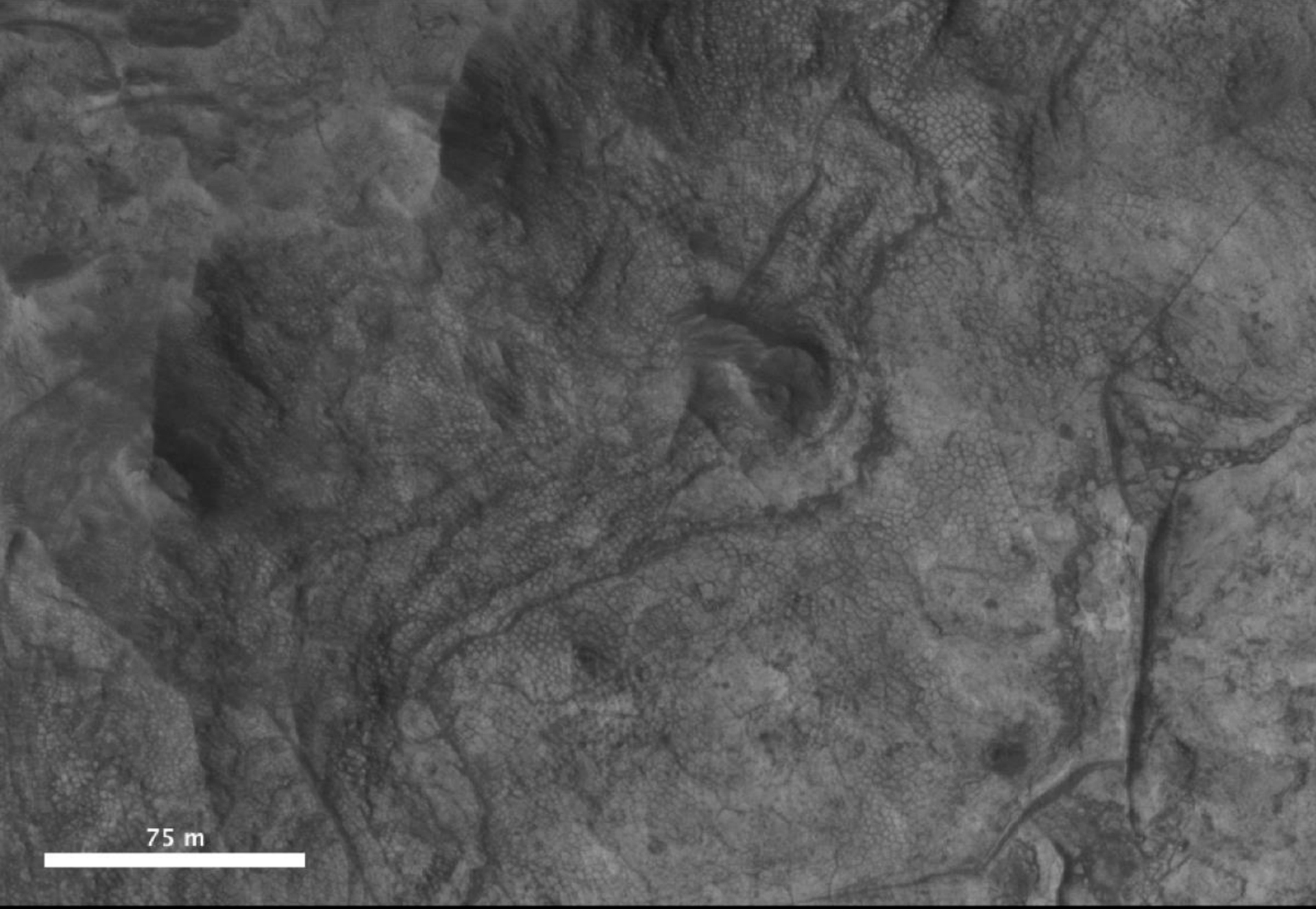
Eberswalde Delta Front

Cliffs Shedding Boulders



Jezero Crater

(1st workshop presentation)

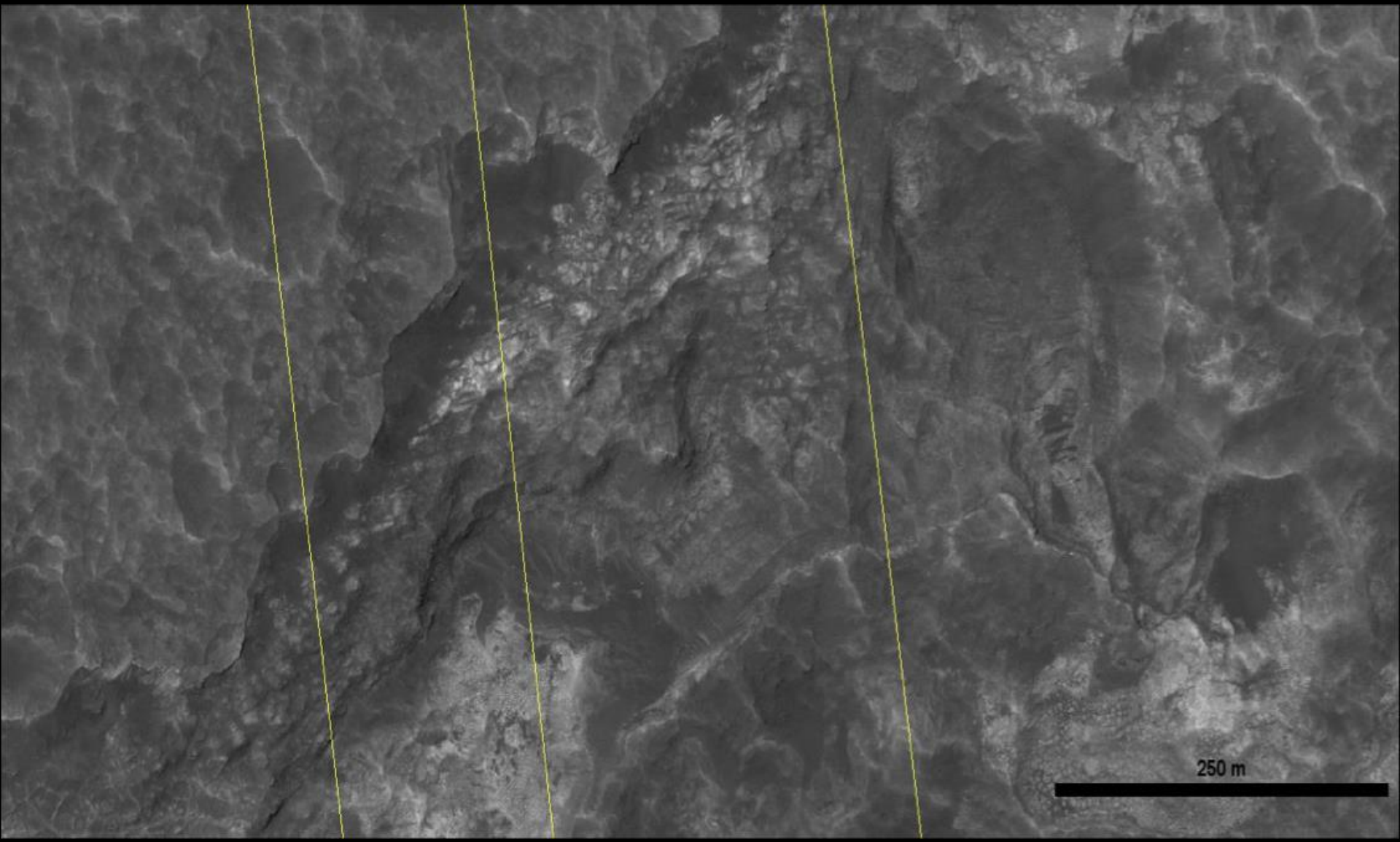


Mawrth

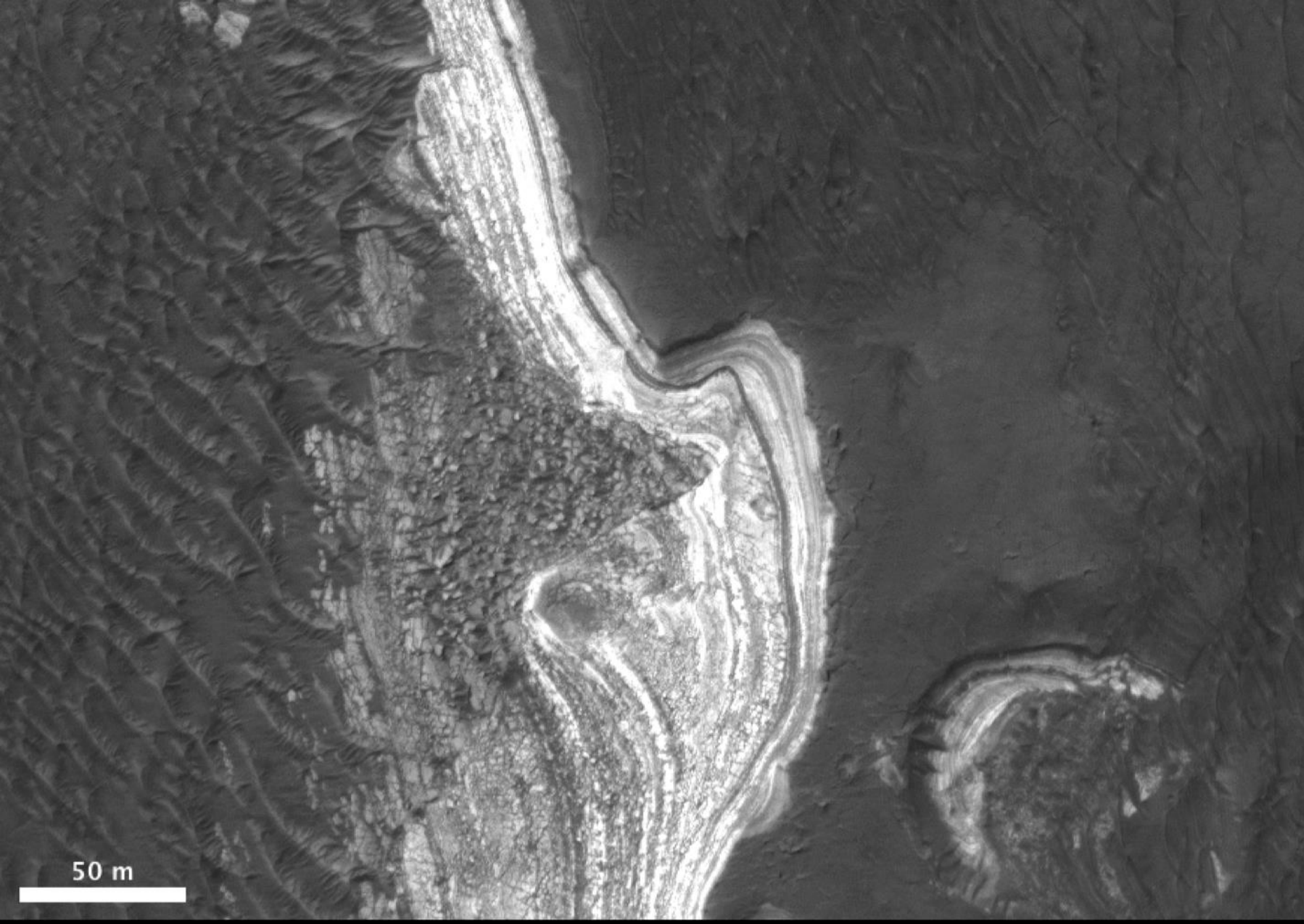
Examples of ambiguous evidence for recent exposure

(tildes in the rubric)

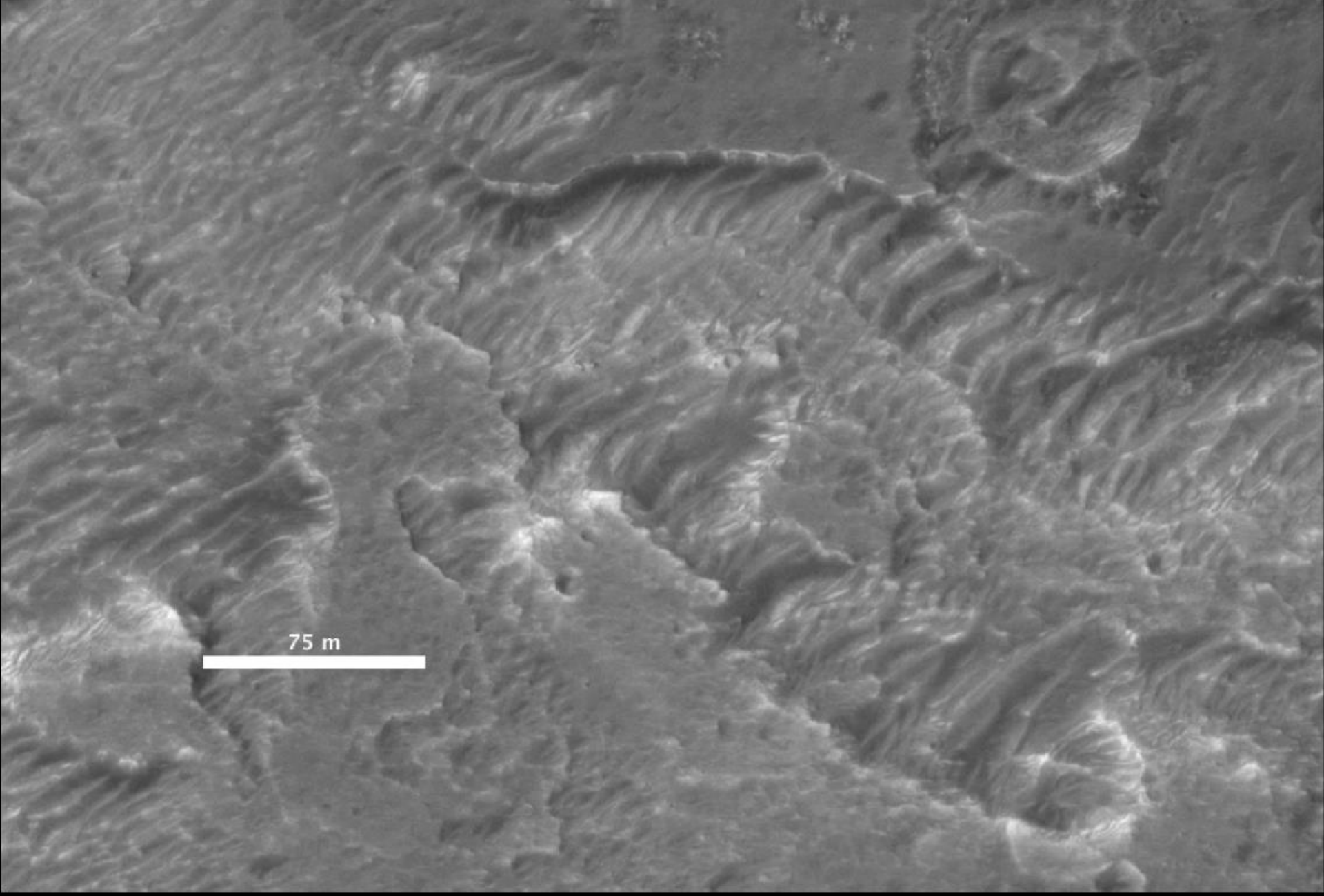
Coprates



Hadriacus



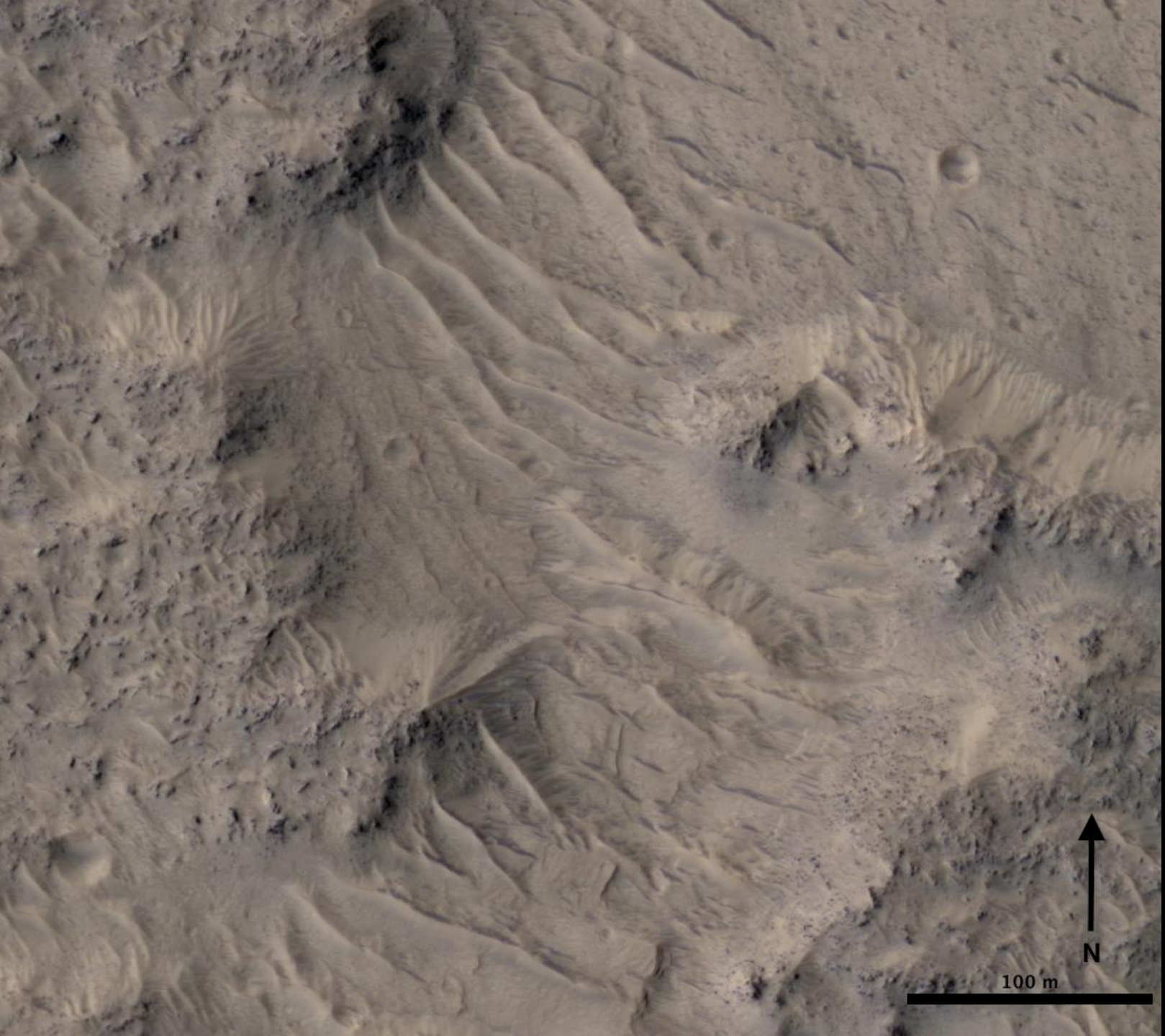
Holden



Oxia

Examples of bad evidence for recent exposure

(blanks in the rubric)



Hypanis